DOCUMENT RESUME

ED 293 724 SE 049 111

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TITLE Analysis and Use of a Task for Identifying Conceptions of Teaching Science.
SPONS AGENCY Wisconsin Center for Education Research, Madison.
PUB DATE Apr 88
NOTE 39p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 5-9, 1988).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Attitude Measures; Beliefs; *Cognitive Structures; *College Science; Higher Education; Interviews; *Preservice Teacher Education; Questionnaires; Science Education; *Student Teacher Attitudes; Surveys; Teacher Education

ABSTRACT

The thoughts that teachers have about the content and students they are to teach influences the way in which they will teach. The purpose of this paper was the development of an instrument to identify teachers' conceptions of teaching science and to review literature concerning this topic. The instrument described was designed to be sensitive to significant distinctions in previously identified dimensions of teaching science. Also described is the framework developed to analyze responses and demonstrate the sensitivity of the task to conceptions obtained from student teachers. The framework for the analyses consists of six categories including: (1) the nature of science; (2) learning; (3) learner characteristics; (4) rationale for instruction; (5) preferred instructional techniques; and (6) conception of teaching science. Having interviewed four students using the instrument, it was determined that the instrument had met its design criteria. Several issues and suggestions for improvement are discussed. (CW)

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ANALYSIS AND USE OF A TASK FOR IDENTIFYING CONCEPTIONS OF TEACHING SCIENCE

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Paper presented at the Annual Meeting of the American Education Research Association, New Orleans, LA, April 1988. Research supported by a grant from the Wisconsin Center for Educational Research.

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INTRODUCTION

The thoughts that teachers have about the content and students they are to teach influences the way in which they will teach. This idea, which accords with common sense and common experience, and is also supported by a growing body of research, lies at the heart of our research, of which the study reported in this paper is a part. The argument is as follows: if we want to improve science teaching (and national reports are calling for just that), and if science teaching depends on teacher thinking, and if science teacher thinking can be influenced by science teacher education, then we need to do research on science teacher certification programs. An important component of such research is the tracking of thoughts that student teachers have about content, how students learn, and how teachers teach, in order to allow questions such as the following to be answered. What thoughts change during certification and induction programs? What thoughts most influence a teacher's teaching? Can teacher education programs be designed which will lead to desirable changes in those thoughts which most influence teaching? This argument demonstrates the importance of the study reported in this paper: the development of a task to identify teachers' conceptions of teaching science.

In the second section of the article we review literature, first, from science education and, second, from teacher education, which has contributed ideas which overlap with one another in interesting ways. In the main section of the article we discuss the task which we have developed to identify conceptions of teaching science. In particular we wanted a task which would be sensitive to significant distinctions in previously identified dimensions of conceptions of teaching science. We also discuss the framework which we have developed to analyse the responses which are obtained from the task, and demonstrate the sensitivity of the task to important aspects of conceptions of teaching science obtained from students at different stages of their secondary science certification program.

LITERATURE REVIEW

The need for a task which can identify conceptions of teaching science is an outcome of recent research in science education. Significant features of this research are considered below in order to outline the foundations of the present work as well as to provide information about the context in which it could be applied. There are, however, also strong resonances between this work and recent research in teacher education which, among other things, has focussed on the relationship between teacher thinking and teacher action. Some important features of research in teacher education are outlined below, and some similarities and differences between the two approaches are pinpointed.

A. Research in Science Education

Students' Conceptions of Natural Phenomena

In recent years, many studies of students' conceptions of natural phenomena have been carried out in different disciplines, in different countries and at all educational levels from elementary school through college graduates. The research has been reviewed in articles (Driver and Erickson, 1983; McDermott, 1984), conference reports (Helm and Novak, 1983), and books (Driver, Guesne and Tiberghien, 1985; Osborne and Freyberg, 1985). This research has shown that, after instruction, students hold a surprisingly wide range of ideas which diverge from accepted explanations. What is more, students' wrong answers are not always random, isolated items of information, but in many cases show a regularity across different students and a consistency within individual studnet responses. This paper refers to these as alternative conceptions. Their occurrence is widespread. Students of a wide range of ages, abilities, grade levels, and nationalities have been shown to hold alternative conceptions in most content areas in science. This extensively documented finding represents a failure in science instruction of considerable magnitude.

Constructivism

A constructivist perspective (Magoon, 1977; Watzlawick, 1984) provides an effective way of interpreting students' responses. Constructivism assumes that humans are knowing, active, purposive, adaptive, self-aware beings whose knowledge and purposes have consequences for their actions. They must construct their own knowledge, using their existing knowledge in order to do so. They construct it in ways which to them are coherent and useful. Even when information is explicitly presented by teachers or textbooks, meaningful knowledge acquisition involves interpretation and integration guided by the learner's own prior knowledge.

The constructivist perspective leads to an interpretation of many of the observed regularities and consistencies in students' responses as alternative conceptions which students hold about the natural world and how it works. Two notable characteristics of alternative conceptions are that they are often significantly different from, and thus alternative to, generally accepted views of the subject; and they are surprisingly resistant to change as a result of traditional instruction (Champagne, Klopfer and Gunstone, 1982). For example, Halloun and Hestenes (1985) found that 44% of 478 college students studying calculus-based physics stated, at least once once on a posttest, the belief that an impetus is required to maintain the motion of an object; 24% were consistent in that belief. When such alternative conceptions persist, their interpretative and integrative functions often lead to misinterpretation of new information or to a breakdown in the sensemaking process and a reliance on rote memorization for coping with the demands of instruction. These characterisitics point to the need to design instruction which addresses such alternatives explicitly.

The conceptual change model and teaching

The interpretation of student responses as alternative conceptions which frequently conflict with those teachers want them to learn suggests that learning may involve changing a person's conceptions in addition to adding new knowledge to what is already there. This view was developed into a model of learning as conceptual change by Posner, et al. (1982)

and Hewson (1981). From this point of view, learning involves an interaction between new and existing conceptions with the outcome being dependent on the nature of the interaction. If these conceptions can be reconciled, learning proceeds without difficulty. If, however, they cannot be reconciled, then learning requires that existing conceptions be restructured or even exchanged for the new. The recognition that change of this nature may have to occur forms the basis of the conceptual change model of learning.

The conceptual change model suggests that science teachers need to know what their students' existing conceptions are, and why they hold them. They can thus more readily assist students to find new conceptions intelligible, plausible, and fruitful, and if necessary can take measures to create dissatisfaction with existing conceptions which conflict with those to be taught. Instruction which has employed these strategies has been successful in obtaining significant change in alternative conceptions held by elementary, middle school, high school, and college students in content areas such as light (Anderson & Smith, 1983), particulate nature of matter (Nussbaum & Novick, 1982), mass, volume, and density (Hewson & Hewson, 1983), dynamics (Minstrell, 1982, 1984), kinematics (Zietsman & Hewson, 1986), and photosynthesis (Roth, 1984). More recently, schemes for teaching aspects of heat, energy, plant nutrition, and the particulate nature of matter from a conceptual change perspective have become available (CLIS, 1987).

Science Teacher Education

Knowing, as a science teacher educator, about research which makes a significant difference to science teaching is one thing. Making this research available to aspiring or practicing science teachers in such a way that they will apply it in their science classrooms is, however, an entirely different matter (Hewson & Hewson, 1987c; Johnston, 1987). Before teachers are going to give valuable classroom time to identifying students' conceptions of natural phenomena, to allowing students opportunity to explore the implications of their views, and to organizing activities which challenge divergent views, they need to be

convinced that conventional teaching strategies with which they are familiar are not at least as effective as those suggested by constructivist teaching approaches. In other words, they need to acquire a constructivist conception of teaching science.

Conceptions of Teaching Science

In using the term 'conception of teaching science' we mean the following: it is the set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature and content of science, and the learners and learning, which the teacher uses in making decisions about teaching, both in planning and execution. These include curricular decisions (the nature and form of the content) and instructional decisions (how the content relates to the learners in the instructional setting). The structure of a conception may vary considerably from a relatively amorphous collection of ideas with no strong connections to one which is interrelated and possesses a large measure of internal consistency. We have elsewhere reviewed the literature in order to identify what an appropriate conception of teaching science is (Hewson & Hewson, 1987a). This included components on teaching, on content, on learners and their knowledge, on learning, and on instruction. Our general conclusions were that science teachers should be able to use their knowledge of the particular content to be taught, the particular students they will be teaching, and effective instructional strategies to plan and perform teaching actions which achieve the intention of helping these students learn the desired content.

Our approach to the problem of how aspiring science teachers acquire appropriate conceptions of teaching science has been assisted by drawing the analogy with acquiring conceptions of natural phenomena. In both cases, people are likely to come to class with existing conceptions which could variously assist or hinder their acquiring of new conceptions. In both cases, people are being asked to come to understandings, meanings, and interpretations of events (albeit with a different focus) which are new to them. In both cases, the guidelines

suggested by the conceptual change model to design instruction are applicable.

There are at least two reasons in support of the analogy. First, the ideas of constructivism are not conditional on the content of people's thought. Different groups of science educators have independently applied constructivist ideas to both science teaching and teacher education (Northfield & Gunstone, 1983; Smith & Anderson, 1984; Osborne & Freyberg, 1985; Erickson, 1987; Driver, 1987.) Second, alternative conceptions of both natural phenomena and teaching science have been documented. The former have been reviewed above. Examples of the latter include didactic, discovery, and activity teaching (Hollon & Anderson, 1987). On the other hand, it could be argued that the differences between scientific ideas and teaching are large enough to invalidate the analogy. For example, a large proportion of teaching time involves a multitude of pragmatic, loosely connected, intuitive activities which do not appear to have any counterpart in scientific conceptions. Particularly in light of the research on teacher education considered below, this argument does not appear to be compelling enough for us to discard the current approach.

The analogy therefore suggests that, just as science teachers need to know what their students' existing conceptions are, and why they hold them, science teacher educators need to know the conceptions of teaching science which students in their certification programs hold. Science teacher educators can thus more readily assist aspiring science teachers to find new conceptions of teaching intelligible, plausible, and fruitful, and if necessary can take measures to create dissatisfaction with existing conceptions which conflict with those to be taught.

B. Research in Teacher Education

Research into teacher thinking has among other things sought to understand teachers' actions in terms of their thought processes. In the Third Edition of the Handbook of Research in Teaching (Wittrock, 1986), Clark & Peterson (1986) outlined one outcome of a National Conference on Studies in Teaching organized by the National Institute of

Education in June 1974. Starting from the premise that it is obvious that there is a connection between what teachers think and what they do, one panel outlined an image of the teacher as a professional whose thought processes were worthy of study. In reviewing what has emerged since then, Clark & Peterson proposed a model which links in a reciprocal relationship teacher thought with teacher action. Teacher thought includes teachers' theories & beliefs, planning and interactive thoughts & decisions, while teacher action and its observable effects includes teachers' classroom behavior, and students' classroom behavior and achievement.

The relationship between teacher thought and teacher action was also considered in Exploring Teachers' Thinking (Calderhead, 1987), in the Introduction to which Calderhead used the metaphor of teaching as a professional, thinking activity. Significant features of the metaphor were that teachers possess a body of specialized knowledge which they have acquired through training and experience, that teaching has a goal-orientation in relation to its clients, and that the problems faced in teaching are often complex and ambiguous.

Calderhead grouped the studies reported in the book into three research arenas. Those of relevance to this paper were exploring the nature and growth of teachers' professional knowledge in the context of influences on it, and the ways in which professional knowledge develops and is used in teaching. Within the first of these arenas, Zeichner, Tabachnik, & Densmore (1987) studied the way teachers acquired "perspectives toward teaching." They used "perspectives" as defined by Becker et al (1961) to be "a coordinated set of ideas and actions a person uses in dealing with some problematic situation." For Zeichner, Tabachnik, & Densmore, important features of perspectives were the ideas that teacher thinking and teacher behavior are inseparable and are both needed for their complete expression, and that they are neither exclusively situation-specific nor automatically generalizable to other situations. Their research showed that while students' perspectives were affected by experiences during student teaching and the first year of teaching, in

most cases this was more an elaboration of existing perspectives than a major change.

Within the second research arena, Wilson, Shulman & Richert (1987) focussed on the subject matter knowledge of preservice teachers. In addition to knowledge about the curriculum, they found that teachers developed "pedagogical content knowledge." This consisted of a range of different representations or transformations of the content by means of which teachers were able to focus on different themes in the content, or adapt the content to different students. Pedagogical content knowledge included "the most powerful analogies, illustrations, examples, explanations, and demonstrations--in a word, the ways of representing and formulating the subject that makes it comprehensible to others" (Shulman 1986, p. 9). Wilson, Shulman & Richert also identified "pedagogical reasoning" as a process of generating and improving these different representations which includes, among other things, transforming content by adapting it to a particular context, and reflecting on its implementation.

Calderhead (1987) identified a number of themes which emerged from the research reported in the book and which linked different approaches and studies. These themes were that teaching is an active process which is based on teacher knowledge, that teachers' thinking is fluid and interactive, and that the nature of teaching is complex and contextualized. Finally, Calderhead suggested that, while research on teachers' thinking was not yet able to provide a comprehensive theoretical framework for thinking about teaching, it did provide insights for future work. Insights of relevance to the topic of this paper were that research on teachers' knowledge bases helps to conceptualize the processes of professional development, that learning to teach is an active process involving a great deal of interaction between thoughts and actions, and that research on teacher thinking should begin to address the issue of students' learning.

In summary, this research has demonstrated that the nature of teacher thinking is diverse, complicated, fluid, and intimately connected in

many different ways with teaching as activity. It is, thus, not surprising that different researchers have focussed on aspects of teacher thinking which frequently overlap, but are not identical. For example, there is overlap between the conceptions of teaching science studied in this paper and the perspectives toward teaching studied by Zeichner, Tabachnik, & Densmore. We include explicit attention to content (in this case, the different sciences) and learning, while they include actions with thoughts and pay more attention to the influence on perspectives of the many aspects of the school system. There is also overlap with Wilson, Shulman, & Richert's pedagogical content knowledge, which does, however, include considerably more specific detail of content than is elicited in the task outlined below.

THE TASK: DESIGN, ANALYSIS, AND USE

A. Design

The aim of the task is to enable a researcher to identify the conception of teaching science which is held by the respondent. Our understanding of the term 'conception of teaching science' was outlined above.

Task Design Criteria

It was decided that the task should attempt to meet, at least, the following design criteria. First, the task should raise, and allow respondents to consider, the components of an appropriate conception of teaching science referred to above. Second, the task should allow respondents to provide a diversity of views about these components, without biasing responses in any particular way. Third, the task should allow respondents to refer to day-to-day classroom events while encouraging them to link these events to ideas in terms of which they could be interpreted.

The Task

The structure of the task is that of an 'interview-about-instances,' a technique developed by Osborne & Gilbert (1980). It is used to explore the concept which a person associates with a particular label, e.g.,

plant, force, or as in this case, science teaching. Each person interviewed is shown a series of instances, originally line drawings, but in this case, short written extracts, and asked whether in his/her view this is an example of the label or not. If necessary s/he is asked if any further information would be needed to arrive at an answer, and then asked to give the reasons which support that answer. The series of instances is chosen to include not only generally agreed examples of instances and non-instances, but also some which are uncertain or controversial. The complete task is given in Table I. The rationale for its design is discussed in Hewson & Hewson (1987b).

The task has a number of desirable features for this project. First, it explicitly provides instances and non-instances of science teaching and learning, both inside and outside the classroom. In other words, it provides a practical, experience-based context for each person's responses. Second, it requires the respondent to focus explicitly on science teaching out of other possible issues which are relevant to the classroom. Third, within this framework it does not prescribe what is important, nor to which aspects attention should be given. A number of instances are, in fact, ambiguous. In other words, we wanted respondents to be able to contribute their own ideas, and focus on what was important or significant to them. Finally, the interview format allows respondents to be more reflective of their ideas, allowing opportunities for reconsideration of earlier statements in light of later instances.

Three different sets of instances have been prepared, with content drawn from biology, chemistry, and physics. For reasons of space, however, only the chemistry set is included. The protocol for the task and the 10 chemistry instances which comprise the task are given in Table I. The summary headings included in the table and used in identifying the items below were not shown to respondents. It is important to note that, while the analysis on which the task was based (Hewson & Hewson, 1987a) produced a set of prescriptive conclusions, the task is a purely descriptive instrument. Thus while the task is designed to help people

consider the issues raised in the analysis, it does not take a position on them.

B. Analysis

Task Analysis Criteria

The aim of an analysis scheme for the task is to provide the researcher with a means of representing the responses obtained from the 'interview-about-instances' task such that it is possible to:

1. determine whether a respondent has considered all significant aspects of a conception of teaching science;
2. determine the extent to which the components of a respondent's conception of teaching science are consistent with each other;
3. compare a respondent's conception of teaching science:
   - with appropriate conceptions of teaching science;
   - with his or her science teaching performance;
   - on different occasions; and
   - with that held by different teachers.

Structure of the Analysis Scheme

The form of the analysis scheme consists of six categories, five of which derive from the components of conceptions of teaching science outlined above and one, preferred instructional techniques, which was included as a result of preliminary analyses of transcripts. The six categories are described in detail below.

1. Nature of Science

This category will include any statement which refers to the content to be taught, the intended object of the teaching, that which the teacher intends the student to learn. The content is science.
There are different aspects of science:

- the natural phenomena which are investigated;
- the methods of investigation used both to produce and to apply knowledge;

- the explanations of phenomena in terms of concepts, principles, theories, etc.;
- the uses to which the knowledge is put including explanation, prediction, application, problem solving, etc; and
- the philosophy within which all these aspects are integrated.

Cutting across these aspects are the different disciplines, e.g., biology, chemistry, physics, etc.

Some examples of students' interview statements in this category are:

"Much of science consists of classification, putting things in boxes;"

"Science is a hands-on type of activity;" and

"Science is what is in textbooks or in schools."

2. Learning

This category will include any statement which refers to learning. There are different aspects to consider. These include:

- learning-as-task (how people learn, the process of learning) which may include behavioral aspects, e.g., reading, summarizing, solving problems, etc., and mental aspects, e.g., knowing, understanding, remembering, thinking, controlling, etc.;
- learning-as-achievement (the product, the outcome, what people have learned) which may include the ways in which the outcome is demonstrated; the type of learning, e.g., propositional, declarative, procedural; and characteristics of what is learned such as permanence, flexibility, and usefulness; and
- a theory of learning which outlines how learning-as-task is linked to learning-as-achievement in the context of other factors (if any).

Some examples of students' interview statements in this category are:

"Learning is repetition;"

"A student can learn from a TV program if he is attentive, concentrating, looking for similarities, differences;" and

"Learning can happen when a student is processing, remembering."

3. Learner Characteristics

This category will include any statement which refers to those characteristics which are likely to influence how and what a person learns. Aspects to consider are:

- the person's knowledge, both cognitive and affective, which may include knowledge of the content, empirical and theoretical; knowledge of the context, including personal, school, and society goals; and personal conceptions of knowledge and learning;
- the person's procedural counterparts of the above knowledge, i.e., knowing how to read, write, enumerate, solve problems, study, etc.;
- the person's approach to the tasks of learning, which may include motivation (intrinsic and extrinsic), behavior and attitude, learning set, surface or deep approaches, etc., all of which are likely to be related to the conceptions of knowledge and learning mentioned above;
- the person's developmental and maturational phase;
- the person's innate capabilities such as the senses, intellectual ability; and
- the context of learning which may include family, school, society, and associated role models.

Some examples of students' interview statements in this category are:

"Good teachers know on what level their students are used to learning;"

"Some content is not in the grasp of some students;"

"The student is motivated to learn when actively involved with the knowledge."

While the focus of this category is different from the previous one, it is obvious that there is a strong relationship between the two. As a result it may often be impossible to place interview statements in one or other of these categories with certainty.

4. Rationale for Instruction

This category will include any statement which refers to the reasons which a person may give for using a particular instructional method. These reasons may be related to:

- the nature of the content as outlined above;
- the learner, his or her characteristics, and learning as outlined above;
- evaluation of the outcomes of instruction;
- the context of instruction, including the setting, whether formal or informal; the constraints, e.g., class size, back-up facilities, weather, season, special events; the curriculum; and society; and
- the teacher's personal expectations, concerns, capabilities, and knowledge.

Some examples of students' interview statements in this category are:

"The teacher should give a quiz so that students get feedback and more repetition;"

"Give students a chance to voice their opinions so that the teacher can get an idea of what they have understood or misunderstood;"

"Bringing specimens around gets students interested."

5. Preferred Instructional Techniques

This category will include any statement which refers to the strategies, techniques, methods, practices which the person would use as being effective in science teaching. These may refer to:

- different phases of teaching, including planning for and preparation of instruction, instructional transactions, and follow-up activities, e.g., homework assignments, evaluation;
- the nature of teacher-student interaction, e.g., agenda control, whether active or passive; and
- the type of instructional technique, e.g., lecture, discussion, lab work, small group work, questioning, etc.

Some examples of students' interview statements in this category are:

"The teacher should show students how to use a heuristic or technique;"

"The teacher should try and create and focus student interest;"

"The teacher should select local examples of flora (regular flowers like a rose or carnation)."

While the focus of this category is different from the previous one, it is obvious that there is a strong relationship between the two. As a result it may often be impossible to place interview statements in one or other of these categories with certainty.

6. Conception of Teaching Science

This category will include any statement which refers to the person's conception of the components of teaching science (outlined in the above five categories) and their interrelationships, e.g., between teaching and learning, between teaching and science, between the nature of science and the characteristics of the learner. It is therefore a category which encompasses the others.

Some examples of students' interview statements in this category are:

"Effective science teaching occurs when students come to own for themselves and understand information that they didn't have before;"

"Science teaching happens when the teacher relates what is happening to scientific concepts;"

"Effective teachers know their audience, and aim at their level;"

"If students ask themselves questions, you can have learning without teaching;"

"You have to have an audience to be teaching;"

"It is not science teaching if no learning, i.e., no understanding, occurred;"

Issues

Two issues in connection with the analysis scheme are important.

1. The categories are not independent of one another, since they represent components of a conception of teaching science. We therefore expect that there are important relationships which exist

between them. The sixth category has been used to include statements which refer to such interrelationships.

2. The categories are broad and, as indicated by the outlines above, there are a number of possible subcategories. The decision to work with broad categories was prompted by three considerations. First, it is not at this stage obvious that a fine grained analysis is necessary in order to compare conceptions of teaching science. Second, it is not clear that it is possible to define subcategories with the degree of precision required to allow statements to be unambiguously categorized. Third, the task of categorizing a statement into broad categories is significantly easier as a result. The present scheme, however, can easily be adapted to allow a more fine grained analysis, should this prove to be necessary.

Use of the Analysis Scheme

In order to prepare summaries which are in a form which allows the analyses mentioned above to be performed, the steps below are followed:

1. The transcript is read and statements which precis the respondent's stated view are recorded. Wherever possible these statements use the spoken words of the respondent in order to ensure that they reflect accurately his or her views. This step is exemplified in Table II.
2. Each statement is then placed within its appropriate category. If a statement applies to more than one category it is placed in both. As was seen above, the categories in some cases do have overlapping boundaries. Table II also exemplifies this step.
3. Within each category, statements which deal with similar aspects are grouped together. Each set of grouped statements is summarized in a single sentence and exemplified by extracts from these statements. This step is exemplified in Table III. Examples of component summaries of different students are shown in Tables IV-VI.
4. The single sentence summaries are then used to provide a final, overall summary which is a representation of the respondent's conception of teaching science. Overall summaries of different students are presented in Tables VII-IX.

The analysis of each interview was done independently by each author, without explicit reference to or comparison with other analyses, and the data were reconciled.

C. Use

This section provides examples of the type of analyses which are possible with the summaries obtained from the task. While these analyses raise many interesting questions about conceptions, e.g., their content, their susceptibility to change, and the effect of potential influences on them, these questions will not be considered in this paper. Rather, the intention is to demonstrate that the task is able to identify a range of important features of conceptions of teaching science. Features which will be exemplified below include similarities and differences between different person's conceptions, the degree of internal consistency of a conception (or lack of it), and the stability of and changes in a person's conception over time.

Use of the Task

The task has been used with 30 students in the secondary science certification program. Of these, 7 were at the start of the methods course and 20 were interviewed towards the end of the methods class. Finally 7 students were interviewed during their student teaching, 4 of them for the second time. All interviews were recorded on audio tape and transcribed.

The examples considered below are from interviews conducted with the four students who have been interviewed twice: first, towards the end of their methods course, in April 1987, and second, towards the end of their student teaching, in November 1987. Ms. Lumley, Mr Jaskot, and Ms Lennon were chemistry majors, and Mr Marcus was a physics major.

Comparisons between Conceptions

Similarities and differences between the components of different students' conceptions will be considered. In each case, a component of Ms Lennon's conception will be compared with the same component of one

of the other three students. First, her views of the nature of science, as exemplified in chemistry, contain a different emphasis than those of Mr Marcus whose science major was physics. The analyses of their views on science, prepared as in step 3 above, are presented in Table IV. Both consider the observation of natural phenomena to be important. Yet while Ms Lennon is sure that observing is science, for Mr Marcus it is the precursor to physics. Next, Ms Lennon is concerned with the meaning of chemical terms and problem-solving processes, while Mr Marcus focusses on providing explanations of why things happen and is much taken with the power of physics generalizations to deal with a wide range of phenomena. For him, problem-solving procedures are not physics. In summary, Ms Lennon places more emphasis on the processes of doing science, while Mr Marcus focusses more on science as a body of knowledge.

Second, Ms Lennon's views on learning and the learner are very similar to Ms Lumley's. The analyses of their views on learning, prepared as in step 3 above, are presented in Table V. Both believe that for students to learn, they need to be active, involved, and searching for meaning. In Ms Lennon's terms, it has to go through their heads, while for Ms Lumley it has to compute in students' heads. Both believe that learners need to be motivated (Ms Lennon speaks of student engagement with the material and investment in a topic) and to possess knowledge (Ms Lumley speaks of a chain reaction of learning), though Ms Lennon emphasizes the former and Ms Lumley the latter. In summary, both view learning as an active process of construction of meaning.

Third, Ms Lennon's views on instructional techniques and their rationale contrast with those of Mr Jaskot. The analyses of their views on instruction are presented in Table VI. For Ms Lennon, the particular instructional technique chosen is less important than the rationale for its choice, since the same technique can serve a range of different purposes. For her, the central purpose is student interaction, and any instructional technique which achieves this is worthwhile. Mr Jaskot's views are similar in that he also focusses on student outcomes as the important goal of instruction; in contrast to Ms Lennon, however, his

preferred techniques are largely teacher-directed. In other words, while both seem to share a common instructional rationale, they differ with respect to the techniques they might use.

Degree of Internal Consistency

Two students will be considered, the other two cases providing similar information. First, Ms Lumley's conception of teaching science, based on her first interview, has much evidence of strong internal consistency between its various components. Her view of learning as an active process aimed at understanding is consistent with her view that students need to be active, involved, and searching for meaning. These aspects are consistent with her view of chemistry as a way of understanding an important part of the world. In turn, her view of the role of the teacher is consistent with her views on learning, learner, and content: there is a joint responsibility to all three which may require the teacher to be directive, interactive, or absent in order to be met. Ms Lumley's overall summaries, prepared as in step 4 above, are presented in Table VII.

Second, Mr Jaskot's conception of teaching science, based on his second interview, has a considerable measure of internal consistency between some, but not all, of its components. There is consistency between learning (an active, sense making process whose outcome is understanding and meaning for the learner) and content (chemistry is understanding and explaining everyday natural phenomena in molecular terms). Further, in Mr Jaskot's view, without learning of this kind occurring, a teacher cannot be said to be teaching. Conversely, if learning is occurring, teaching happens even in the teacher's absence. On the other hand, his instructional techniques focus largely on teacher activity (assigning problems, doing demonstrations, giving theoretical background, etc.) with some interactive techniques (asking questions, starting a discussion, etc.) It is not clear from his interview whether he sees the need to reconcile these two points of view and, if so, how he would do so. Mr Jaskot's overall summaries, prepared as in step 4 above, are presented in Table VIII.

Stability over Time

Three students will be considered since they represent the range of variation observed. First, Ms Lumley's conception of teaching science showed very little change from the first interview to the second. With respect to learning and the learner, she put more emphasis on the knowledge of the learner in the second. With respect to teaching, she was more insistent that teaching cannot have occurred without quality learning taking place in the second interview. Her views of chemistry and teacher roles were almost identical in both interviews. Although expressed in different terms, her conception of teaching science remained essentially unchanged. Ms Lumley's overall summaries are presented in Table VII.

Second, there were strong similarities between the first and second interviews for Mr Marcus, with one aspect noticeably elaborated in the second interview. His views of physics remain essentially unchanged: it is able to explain the world in an organized, simple way. Learning on both occasions for him requires students to be active, motivated, and possessing knowledge, though in the second interview he elaborates considerably on learner's knowledge (they possess it, they use it as background to and as an anchor for new ideas, but it can be different than the teacher's views.) The role of the teacher on both occasions is a dual one, encouraging student activity and presenting physics. In the first interview, however, he expressed the view that teaching involves the teacher responding to questions and adapting to the audience, while in the second he said that teaching could occur even without student learning happening. Mr Marcus' conception of teaching remains identifiably the same, however, with some changes and elaborations. His overall summaries are presented in Table IX.

Third, there is a considerable change between the first and second interviews for Mr Jaskot. These changes are predominantly additions and elaborations. In the first interview he hardly spoke of science; in the second he expressed the view that chemistry is understanding and explaining everyday natural phenomena in molecular terms. In the first

interview he briefly mentioned that learning requires active involvement with content and leads to understanding; in the second he provided more detail of these aspects and included the need for learning to have a knowledge base. In the first interview he saw the goal of instruction as student understanding; in addition in the second interview he called for the teacher to be more directed, thus setting up the potential conflict discussed above. Thus Mr Jaskot's conception of teaching science developed considerably between the two interviews. His overall summaries are presented in Table VIII.

Some confirmation of these analyses comes from the students themselves. All four were given copies of the analysis and summary of their first interviews when interviewed a second time. Mr Jaskot commented about the changes; the other three all felt that the initial analysis and summary accurately represented their views.

DISCUSSION

The task which we have outlined in this article was designed to identify a teacher's conception of teaching science, i.e., the set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature and content of science, and the learners and learning, which the teacher uses in making decisions about teaching, both in planning and execution.

In planning the task we felt it was important that the task should meet different design criteria. First, we thought that the task should raise, and allow respondents to consider, the range of components of an appropriate conception of teaching science. The analyses presented above give ample evidence that this was so. Second, we thought that the task should allow respondents to provide a diversity of views about these components, without biasing responses in any particular way. The analyses presented above revealed many differences between the four students who were interviewed. Some of their views were clearly distinct. For others, the differences were subtle nuances. There were also some strong similarities across all four students. Particularly in

light of initial analyses of other students which revealed much greater differences between conceptions than occurred here (Hewson & Hewson, 1987b), we feel optimistic that the task does not bias responses while allowing differences both major and minor to emerge. Third, we thought that the task should allow respondents to refer to day-to-day classroom events while encouraging them to link these events to ideas in terms of which they could be interpreted. The above analyses clearly provide evidence that this occurred. In summary, we believe that the task meets its design criteria.

The task analysis scheme which we developed to represent interviewees' responses was designed to meet the following criteria: it should be possible to determine the components of a conception of teaching science, determine their interrelationships, and compare them in different ways. With respect to the first two criteria, the range and length of the interview (10 instances and 30-40 minutes discussion) provide ample opportunity for interviewees to consider the different components of their conceptions and the interrelationships between these components. These are the factors which contribute to the consistency of a person's conception of teaching science. The examples discussed above show that the interview task can be used to identify differences in the extent to which a person's conception is internally consistent.

The form in which the analysis was presented allowed the third criterion to be met. Comparisons were drawn above between the internal consistency of a student's conception, between different students' views of the same components, and between the same student's conception at different times. Although they were not reported in this article, the format clearly would also allow other comparisons to be made between a student's conception and, e.g., his or her teaching performance, or conceptions shown to be desirable in the research literature. In summery, then, we believe the task analysis scheme meets its design criteria.

We do have some concerns about the analysis technique. First, the original interviews are rich in detail. In any process of abstraction,

there is the ever-present danger of reducing the data to inappropriate and trivial labels--we feel reluctant, for example, to term this teacher a didactic teacher, that one a discovery-oriented teacher, partly because it washes out the interesting nuances between teachers. It may, of course, be that these are insignificant in the long term, but at this stage we have chosen to err on the side of retaining too much information rather than too little. Second, the technique is time consuming. It can thus only be used as a research tool. While we believe that it is time well spent, it is early to form a final judgement on this question.

Other issues about the task have emerged as we have used it with different people. It provided an experience which respondents felt was significant. They found that it made them think very hard about what was involved in science teaching. Thus, it constitutes a powerful intervention technique. Respondents found that they needed to reconsider their answers as they worked through later items, particularly because it illuminated possible conflicts in their own thinking of which they had been unaware. The fact that the task constitutes a powerful intervention is one that needs to be considered. It will obviously make it difficult to identify the source of changes which might occur between successive interviews. The task does not, however, stress a particular conception of teaching science, so it is plausible that the major effect of the intervention will be to help the person clarify his or her existing views, rather than leading to major changes in those views. That some conceptions remained essentially unchanged over seven months is perhaps evidence to support this position. At this point, however, the advantages of the task appear to us to be sufficiently clearcut that we are prepared to accommodate the issue of its influence. From an instructional point of view this aspect may indeed prove to be a virtue.

It is clear that the information which the task provides is not complete. While it focusses on the components of a conception of teaching science and their interrelationships, the literature review points to the need to supplement the information obtained by the task in

at least two ways. Respondents' teaching needs to be observed, and the detail of their pedagogical content knowledge needs to be ascertained. The results of these investigations need to be integrated with those obtained using our task. Having accomplished this, we are optimistic that we will be closer to the goal outlined at the start of this article: being able to design more effective teacher education programs.

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TABLE I

INTERVIEW-ABOUT-INSTANCES OF SCIENCE TEACHING

PROTOCOL:

1. In your view, is there science teaching happening here?
2. If you cannot tell, what else would you need to know in order to be able to tell? How would this information tell you? Please give reasons for your answer.
3. If you answered 'yes' or 'no', what tells you that this is the case? Please give reasons for your answer.

ITEMS:

1. Handing out crystals
   Teacher in a middle school at the start of a topic on crystals, asking the class, "What can you tell me about the crystals I've passed around the class?"

2. Student watching TV
   A student at home watching a TV program on chemical plants which produce new plastics from coal.

3. Students in library doing problems
   Two 10th grade students in a library working on a set of vapor pressure problems from the chemistry textbook given for homework.

4. College professor and first graders
   College professor lecturing on molecular orbital theory to a small group of first graders.

5. Teacher describes algorithm
   Teacher in front of 10th grade chemistry class, describing the steps used in the factor-label method of solving mass-mass problems.

6. Teacher questioning student statement
   Teacher reads a 10th grade chemistry student's statement that 'Ideal gases have no volume' and asks, "Were you referring to the gas particles or the gas as a whole?"

7. Teacher asks students to label diagram
   Teacher at end of a demonstration of the electrolysis of water distributes a drawing and asks students to label the apparatus used in the experiment from memory.

8. Student asks question
   Junior high school student in class, watching an experiment on the electrolysis of water which has been going for some time asks the teacher, "Do you think you've got all the oxygen out of there yet?"

9. Student making muffins
   A student at home following a recipe for blueberry muffins.

10. Teacher writing self study program
    A teacher, writing a self-study resource center program at home on using the triple beam balance to measure the weight of an object.

TABLE II

TRANSCRIPT, STATEMENT GENERATION, AND CATEGORIZATION

Ms Lennon, Second Interview, Instance No. 2

S (Student): A student at home watching a TV program on chemical plants which produce new plastics from coal. Oh, chemical plants, not plants.

I (Interviewer): Is there any chemistry teaching going on there?

S: Okay, that's one where it might, might not. And it partly depends on student motivation. If that student is watching television to fill time or if it's simply watching without interacting and thinking about what's going on, I would have to say probably not teaching. If that student is then either interacting with the television program, the student has an assignment that they're going to have to complete based on that program. If there's some interaction going on, then yeah, there could be teaching. The question is who's teaching, partly and that could either come from a classroom, in other words, there's an imposed structure on why this student is watching this program and then I would say it's the classroom teaching. If it's simply student motivation, that student is motivated to find out about plastics made from coal, I think students can in fact be taught by an inanimate object like a television set. Certainly, there's learning going on which is one half, so by extension you could say there's teaching; something is teaching.

I: You said one of the keys to all this was that the student was interacting. [R: Right.] Now, can you expand on your understanding of interaction?

R: Well, I guess what I mean is that there has to be, in any, if you believe as I do that teaching and learning are two halves of a process, there has to be at least some level at which the student is working on processing, whether it's producing some questions, whether it's simply individually going through and saying to themselves, "do I understand what that means?" or "but what about this?" There has to be some student engagement that's very hard to define, operationally, with the material that's the subject of the teacher and probably also with the vehicle of teaching which would be a teacher, or perhaps a video tape or whatever. The limit then will be the subliminal teaching, I couldn't handle that. There has to be sort of an active, but at least that internal activity of thinking about what's going on.

Table II (continued)

I: Okay. Is that chemistry?

R: Could be if it's about the sociology of the chemical plants which produce plastics from coal, it doesn't have to be. But certainly the idea that plastics can come from coal is chemistry. I don't know how much of that, how detailed one would have to be with a high school student.

Statement Generation and Categorization

It partly depends on student motivation if teaching is going on. (The learner)

If students are motivated to find out about plastics made from coal, they can be taught by an inanimate object like a TV set. (The learner, Teaching)

If there's some interaction going on, then there could be teaching. (Teaching)

It's classroom teaching if class imposes structure on why student is watching TV program. (Rationale for Instruction, Teaching)

If there's learning going on, which is one half, by extension you could say there's teaching. (Teaching)

Interaction means student is working on processing at least at some level, whether producing questions, or going through, asking themselves questions. (Learning, The learner)

Interaction means there has to be some student engagement with the material, and probably also with the vehicle of teaching. (Learning, The learner, Teaching)

The idea that plastics can come from coal is chemistry. (Science)

TABLE III

STATEMENT GROUPING AND SUMMARY

Ms Lennon, Second Interview, The learner

Group 1

At high school the teacher is held responsible for students who aren't motivated.
If a student actually produced a question, s/he will have use and investment in answering it.
If students are motivated to find out about plastics made from coal, they can be taught by an inanimate object like a TV set.
Interaction means there has to be some student engagement with the material, and probably also with the vehicle of teaching.
It partly depends on student motivation if teaching is going on.
Student investment in a topic is what the teacher really is aiming for. Once it's there it makes it go.
If students are working together, helping each other understand, they may be teaching each other, assuming it's more than a rote problem.
Interaction means a student is working on processing at least at some level, whether producing questions, or going through, asking themselves questions.

Group 2

It's teaching if activities are set up in a student's head - rarely by student, generally by someone else.
It's teaching if the teacher taps into students' previous experience and knowledge about crystals or whatever it is she's passing around.
A student statement, telling you how he understands what he's seeing, is a wonderful opportunity for teaching, it's part of teaching.

Summary of Ms Lennon on The learner

Ms Lennon sees two important characteristics of learners. The first is their motivation, engagement, investment in the task, and independence. For her, it partly depends on student motivation if teaching (and learning) is going on. Also if they are motivated to find out about plastics made from coal, they will learn from an inanimate object like a TV set. She wants student engagement with the material and, particularly, student investment in a topic which happens when a student actually produces a question. A second characteristic of learners is what is in their head. This includes previous experience and knowledge, e.g., of crystals, activities which are set up in the student's head, and understanding of what he or she is seeing.

TABLE IV

COMPARISON OF VIEWS ON SCIENCE

Ms Lennon, Second Interview; Mr Marcus, Second Interview

Ms Lennon on The Nature of Science

With respect to the nature of science as applied to chemistry, Ms Lennon stated that observation was important. For her, observing crystals, using observational skills is certainly science and it is going to be the basis for chemistry, for talking about crystals and chemical principles. Next, chemistry involves understanding and meaning. For her, really understanding chemistry is knowing where oxygen comes from, knowing what chemical equations and formulas mean, going beyond algorithmic problem solving steps to a way of analyzing problems by saying where do I want to end up and how am I going to get there. If, however, the formal reasoning behind an algorithm isn't there, it's probably not chemistry but math. Finally, chemistry involves ideas. For her, the idea that plastics can come from coal is chemistry.

Mr Marcus on The Nature of Science

Mr Marcus had a number of things to say about the nature of science with specific reference to physics. First, physics deals with natural phenomena. It starts with looking at the world around us, looking at crystals and asking: what do I see in this crystal? The observation itself, however isn't active physics, but a precursor to physics. Second, for Mr Marcus the goal of physics is to explain the world in an organized way. Thus it is involved in wondering why a cup prevents cold from getting into a student's hands, why a triple beam balance or a transformer or magnetic induction works, why solar power generates electricity. It is to have students see what's behind the problem. Alternatively it is more than going through the procedures and more than labelling the parts of a transformer, because students don't have to know what's going on to do that. Third, physics' explanations are, for Mr Marcus, simple because physics is a way to generalize the world into different situations which are basically the same, e.g., Newton's Laws apply everywhere, from someone walking across the floor to the earth moving around the center of the universe. Finally, procedures are important, but are not physics, in Mr Marcus' view, even though they are close to it. For instance, following a recipe isn't physics, it's like learning the procedure to solve free body problems in dynamics, or how to use a balance.

TABLE V

COMPARISON OF VIEWS ON LEARNING AND THE LEARNER

Ms Lennon, Second Interview; Ms Lumley, Second Interview

Ms Lennon on Learning

For Ms Lennon learning is a process which requires the learner to be active, interactive, involved. She wants students to think about oxygen, hydrogen, ions, gases, electricity flowing through a medium, and the chemistry of what a gas is. For her, students need to work on processing at some level by going through and asking themselves questions, to be engaged with the material and probably also with the vehicle of teaching (teacher, book, TV, etc.). She wonders how students are going to see something, what they are going to learn from it, whether they are going to understand it. Alternatively, for her it isn't worthwhile if students commit to paper something that hasn't gone through their heads. She sees two important characteristics of learners. [See Table III]

Ms Lumley on Learning

For Ms Lumley, learning is essentially a mental task. Information in order to be learned has to compute in students' heads. This means that students use their thought processes and think critically. In doing so they must use their background experiences and relate the topic to what they know. Without this, any student output would be nonsense. Learning, for Ms Lumley, is only achieved when students really internalize what they are seeing, when it means something to them, when they understand it. This entails them seeing it as part of a complete process. For example, the periodic table is necessary for the beginning of a chain reaction of learning. For learners to engage in the type of learning envisaged by Ms Lumley, they need background experience and they need to know things to which new ideas can be related. Without this, learning is meaningless nonsense. In addition, learners need to pay attention, to think, to compute, to be able to relate concepts to what they know.

TABLE VI

COMPARISON OF VIEWS ON INSTRUCTION

Ms Lennon, Second Interview; Mr Jaskot, Second Interview

Ms Lennon on Instruction

With respect to instruction, Ms Lennon's views are largely focussed on the rationale for instruction rather than on specific instructional techniques. Her concentration on rationale rather than technique probably arises from her view that a specific instructional technique, e.g., having students label apparatus, can be used for different purposes, e.g., as a first step to talking about the whole electrolysis process, getting students to start thinking, or simply an exercise for putting another grade in the gradebook. Her rationale is very largely student centered. She wants students to be challenged and motivated, to observe, to start thinking about chemicals, to build a basis of knowledge, to really understand chemistry. In order to do this the teacher should react to student statements, get other students reacting, set up situations which allow student understanding, require students to think, get students observing, and tap into previous knowledge. To sum up her view, she would really gear the material to the students so that it's in a form in which they can interact with it.

Mr Jaskot on Instruction

With respect to instruction, Mr Jaskot's preferred techniques were largely teacher-directed, but focussed on student and subject outcomes. Thus the teacher should assign problems, write up worksheets, develop ideas, do demonstrations, and use common items, so that students could have understanding, see the reality of the chemistry, and be interested enough to ask questions and follow the chemistry. Talking about possible reasons for the failure of a lab, giving theoretical background, and using everyday things were ways by a which a teacher could show that chem is not cut and dried, that it's a science that's being developed, and that it isn't an abstract subject they need to take for college. More interactive techniques included asking questions such as what's going on inside? why is it hooked up like this? and probing either/or questions, getting students' hands on in the lab, having them find out on their own. These techniques could start a discussion off, keep students interested, and even get them to ask good questions about the topic.

TABLE VII

OVERALL SUMMARIES: Ms Lumley

Overall Summary of Ms Lumley's First Interview

Ms Lumley's conception of teaching science includes teacher, student, and content. It is focussed most clearly on the student who needs to learn how to do, to understand, to apply chemistry. The student's role is to be active and involved with content, with peers, with the teacher. She hopes that students will go beyond symbols and facts to the underlying meaning of chemistry. Her view of chemistry is also clearly defined; chemistry is a way of understanding an important part of the everyday world. Finally, for her, the teacher's role is to ensure that students learn chemistry by whatever means, whether by direct exposition and explanation, by activities which encourage student activity and involvement such as questioning, or by getting out of the way if students are learning on their own.

Overall Summary of Ms Lumley's Second Interview

Ms Lumley's conception of teaching science includes teacher, student, and content. It is strongly student centered with the key criterion being that without quality learning there can be no teaching. She sets a high standard for the quality of learning: students need to be knowledgeable (their knowledge is necessary to link to new ideas and provide meaning) and active (critical thinking requires effort). In her metaphorical terms, students need to compute, to follow a chain reaction of learning. Her view of the student is closely tied to her view of content. Chemistry is a way of understanding the world by using a large connected base of knowledge to explain natural phenomena. In other words it involves a good deal more than information about the world, or simply making things happen. Active knowledgeable students are required to learn explanatory chemistry. Her conception of the teacher accords with her views of student and content: the teacher's role is to do whatever is necessary to help her students learn chemistry. This requires some direction, much interaction, and an awareness of the need sometimes to let students do it for themselves.

TABLE VIII

OVERALL SUMMARIES: Mr Jaskot

Overall Summary of Mr Jaskot's First Interview

In summary, Mr Jaskot's conception of teaching science includes both teacher and student. He is clear about a teacher's reponsibilities: these are to present the content, find out if students understand it, and do what is necessary to correct their misunderstandings. As far as students are concerned, he recognizes that learning is an active process on their part, and sees the need to use instructional strategies which encourage that. Finally, for Mr Jaskot, the above considerations appear to be independent of the nature of the content he is teaching.

Overall Summary of Mr Jaskot's Second Interview

Mr Jaskot's conception of teaching science consistently includes teacher, student, and content. He sees that the teacher has a dual responsibility--to both content and student. Chemistry is the understanding and explanation of natural phenomena which occur in the everyday world in atomic and molecular terms, so teaching chemistry requires the teacher to go beyond features which are immediately observable. Students learn by being active and seeking to make sense, the outcome of their learning should be understanding and meaning, and this type of learning is dependent on their existing knowledge. Mr Jaskot is clear that teaching only happens when students learn in this way. Yet his instructional techniques, which in his view have the purpose of facilitating this type of chemistry learning, are largely teacher directed, some being directive and others being more interactive.

TABLE IX

OVERALL SUMMARIES: Mr Marcus

Overall Summary of Mr Marcus' First Interview

In summary, Mr Marcus' conception of teaching physics includes teacher, student, and content. He is clear about the relationship between teacher and content: it is his responsibility to present the content of physics explicitly, and he is clear about what does and does not count as physics. He also sees a relationship between teacher and student: students learn when they are active, questioning, involved. His responsibility is thus to encourage this type of learning, to set the scene and allow them to get on with it. His preferred instructional techniques are consistent with these dual responsibilities. Finally, while he mentioned the knowledge held by students, he did not address what his approach would be if he found it to be unsatisfactory.

Overall Summary of Mr Marcus' Second Interview

In summary, Mr Marcus's conception of teaching science contains strong connections between teaching and the learner. For him, students' knowledge plays an important role in how they handle instructional tasks, and so it is not surprising that teaching, for Mr Marcus, requires interaction between student and teacher. Thus for him a very important instructional strategy is questioning. He also feels that the teacher needs to play an active role, possibly deriving from a responsibility to his subject, physics, which he sees as being able to explain the world in an organized, simple way. He recognizes, however, that students find this a difficult view to accept. Finally, he does not say much explicitly about the outcomes of learning which he desires, nor how they can be achieved.